PIER ESI Transmission Workshop

Transmission R&D Assessment
Interim Report Findings

March 12, 2003

Navigant Consulting, Inc.

San Francisco, California
Rancho Cordova, California
Burlington, Massachusetts

We have three objectives for the overall workshop….

- *Describe the methodology employed in the assessment*
- *Present the findings and observations from our analysis*
- *Generate valuable discussion among workshop participants regarding key issues*

Workshop Presentation Agenda

1. Methodology
2. Findings & Observations

The goals of NCI's Transmission R&D Assessment are to support the CEC PIER's development of a five year research plan for transmission:

- Characterize the research objectives (e.g., increase capability, enhance reliability, reduce operations costs, defer new construction, etc.), scope, budget and timeframe for research already performed, underway or planned in the transmission arena.
- Identify and prioritize the research gaps that the CEC could address with its research program.
- Develop recommendations for the research portfolio of initiatives to meet and close the identified gaps, including a preliminary portfolio balancing.

Navigant Consulting's (NCI) Transmission R&D Assessment is comprised of five interconnected sets of activities.

- Conduct literature search
- Conduct web search
- Identify research hubs
- Interview key individuals at hubs and other stakeholders

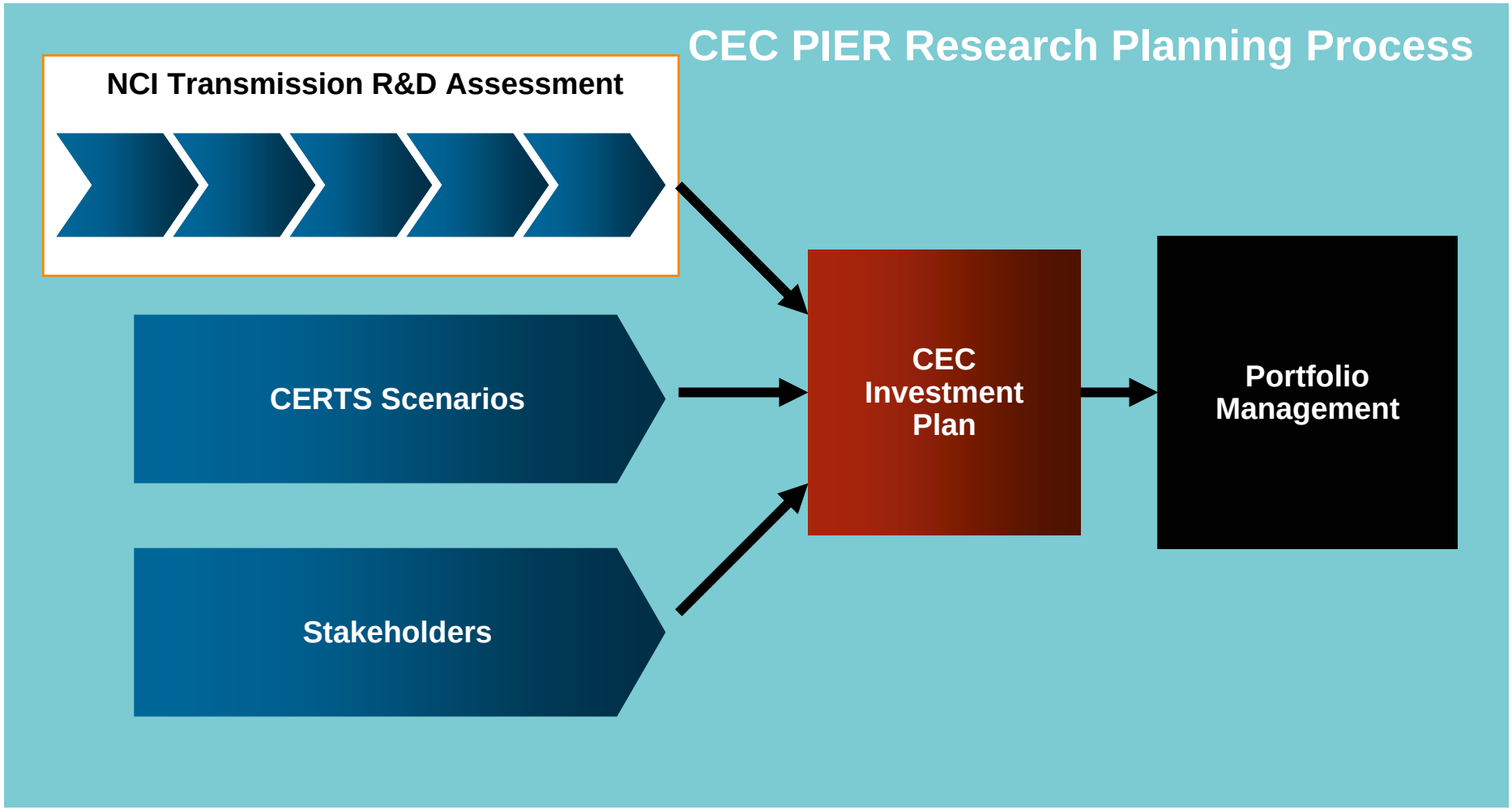
- Develop initial analytical framework
- Categorize project information
- Analyze information

- Refine analytical framework and produce initial assessment
- Produce an initial draft interim report
- Obtain feedback and revise draft interim report

- Submit interim report
- Obtain input from workshop
- Analyze feedback from workshop

- Incorporate workshop feedback into report
- Complete and submit final report
- Work with PIER ESI to create foundation for balanced portfolio of transmission R&D projects

The NCI Transmission R&D Assessment will contribute to the goal of developing a portfolio of research projects for CEC PIER.

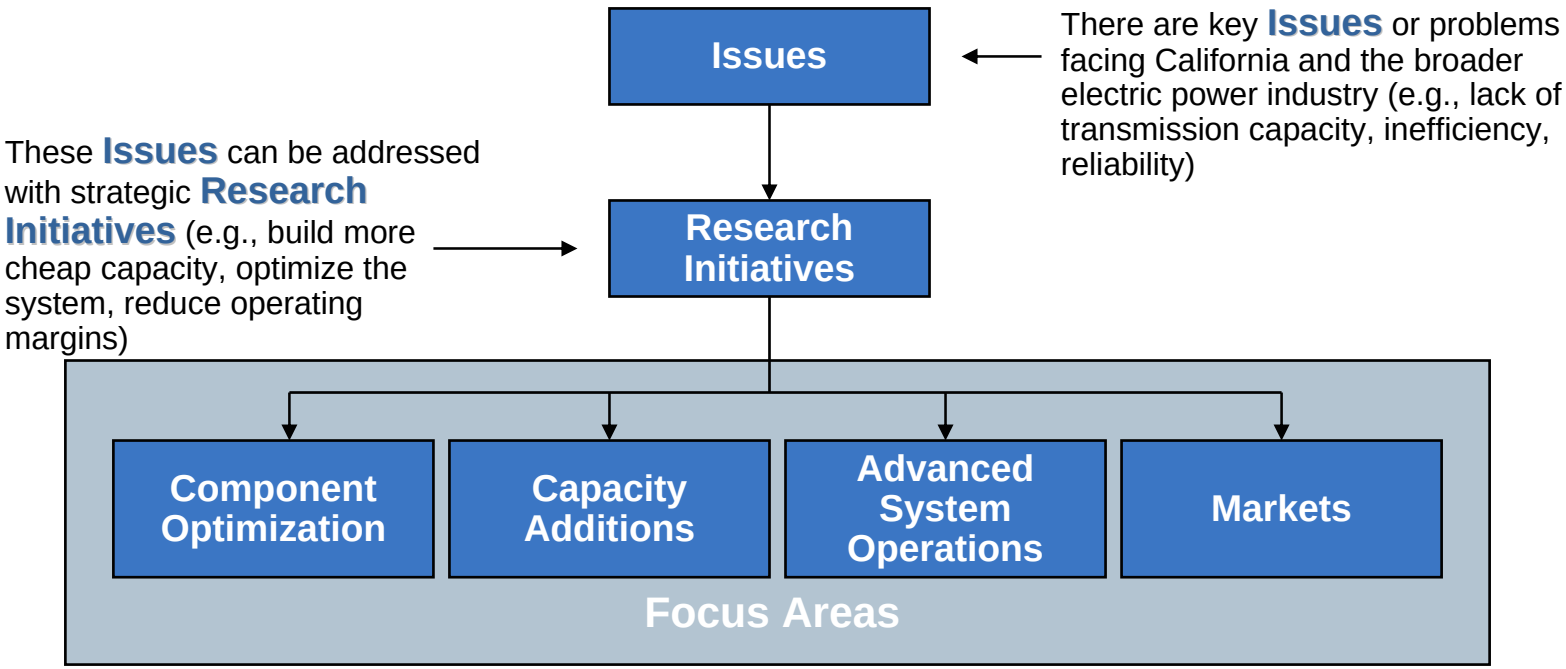


The transmission industry has a unique set of characteristics with respect to R&D.

- Relative lack of historic competition
- Participants often appear to be risk averse and conservative regarding investments
- The transmission industry is relatively mature
- Research often takes place through collaborative efforts and research consortiums, sharing both risks and rewards, for example:
  - EPRI
  - CERTS
  - PSERC

An assessment framework was created.

Transmission R&D Assessment Framework



Research and development currently underway or planned is working to solve very specific problems. The assessment grouped the projects into **Focus Areas** that more clearly support the **Research Initiatives** and **Issues**.

The key issues were identified in the form of critical questions.

Are there research, development, demonstration or commercialization opportunities that can enhance transmission reliability and capability in California?

Component Optimization

Are there technologies that can increase or optimize the capacity and reliability of the existing transmission components?

Capacity Additions

Are there technologies that will provide a quantum leap in transmission capability or simplify adding new capacity?

Advanced System Ops

Are there technologies that can increase transmission capability through advanced information management and control of the power system?

Markets

Can market models or operations be improved to encourage transmission investment or optimize transmission resources?

Note: For the purposes of this work, “technologies” include hardware, software, and innovative tools or applications

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Component Optimization Issues and Research Initiatives

Issues	Research Initiatives
• **Can the ratings of existing equipment/components be increased?** • **Can we reduce the operating reserve margins of the system?** • **Can the system be modified to meet changing conditions?**	***Ratings & Operating Limits*** • Use actual system conditions in place of worst case conditions to increase thermal and stability limits • Improve the cooling capability of equipment • Develop new operating techniques
• **Can technology be applied to increase the reliability and/or availability of equipment?**	***Equipment Reliability & Availability*** • Adopt advanced materials that enhance the durability of system components • Employ advanced design techniques that enhance the durability of system components • Reduce outages due to equipment failure (e.g., preventive/predictive maintenance)
• **Can we make the system less vulnerable to environmental conditions and terrorism/vandalism?**	***System Reliability & Security*** • Increase the precision of system protection/operation • Reduce the impact of environmental conditions (e.g., lightning, fire, storm, salt) and terrorism • Design systems/system components to withstand seismic events • Design systems/system components to improve performance of transmission facilities experiencing geomagnetically induced currents

Component Optimization Issues and Research Initiatives

Issues	Research Initiatives
• **Can we decrease the time required to restore failed components?**	***System Restoration*** • Develop self-healing networks • Improve fault location identification to decrease restoration time • Optimize/prioritize system restoration against various criteria • Novel equipment/configuration design to manage failures and rapid system restoration • Mechanized/automated repair
• **Can we increase the efficiency of system components?**	***Equipment Efficiency*** • Develop materials to increase efficiency of system components (e.g., HTS, ceramics, carbon fiber) • Reduce the cost of transmission related technologies and components • Develop designs/configurations to increase efficiency of system components • Apply storage technologies to enhance transmission capabilities

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Capacity Additions Issues and Research Initiatives

Issues	Research Initiatives
• **Can we upgrade system elements to increase their capacity (e.g., voltage, conductor)?**	***System Upgrades*** • Increase operating voltage • Increase the capacity of the conductor • Increase transfer capability/limits
• **Are there novel component configurations to increase capacity (e.g., AC to DC conversion, phase orientation, corridor design, underground)?** • **Can we site, permit and construct new facilities in a timely fashion?** • **What are the technical/market limitations or tradeoffs between generation and transmission?** • **Do we understand the complex set of values/benefits that transmission provides the power system?**	***System Configuration*** • Increase/simplify the application of DC transmission • Develop novel phase configurations to increase capacity • Develop novel configurations to reduce environmental/public impact (e.g., aesthetics, EMF, wetlands, wildlife)
• **Do new transmission components offer significant increases in capacity?**	***New Components*** • Increase the capacity of transmission components (e.g., conductors, transformers, towers, insulators, underground cable, etc.)

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Advanced System Operations Issues and Research Initiatives

Issues	Research Initiatives
• **How can we improve the integration of power system components?** • **What are the practical limitations of transmission system size and scope?** • **What are the anticipated values/benefits of improved system operations?**	***System Operability*** • Develop substation automation • Develop enhanced communications architecture • Integrate and streamline database and information systems • Develop expert systems to carry out complex control orders
• **How can we improve the quality and quantity of operating information?**	***Operating Information*** • Develop operating condition monitoring (e.g., power flow, voltage, temperature) • Develop presentation and communication tools for operators (e.g., outage mapping, congestion profiling) • Develop advanced decision support tools (e.g., optimal power flow, real-time security assessment, dynamic scheduling) • Develop tools for obtaining and presenting system information for planning purposes

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Markets Issues and Research Initiatives

Issues	Research Initiatives
• **Are current market designs inhibiting the development of new transmission facilities?**	***Market Design*** • Develop mechanisms to value and assign capacity rights • Determine appropriate ancillary services • Develop effective hedging instruments • Develop modeling tools to test and simulate markets
• **What information and tools are needed to improve market performance?** • **What is the optimum balance between system operations (ISOs), asset management (owners), and markets (buyers and sellers)?**	***Market Operations*** • Identify ISO and Transmission Ownership requirements • Provide information and analysis to support bidding strategies • Develop systems to ensure transaction compliance • Develop rules and systems for congestion management

Markets Issues and Research Initiatives

Issues	Research Initiatives
• **Is the level of risk or the perception of risk preventing the development of new transmission facilities?** • **Can the transmission system provide a broader range of products or services?** • **What is the tradeoff between market standards and product innovation and value?** • **Are current transmission business models compatible with future markets and regulation?**	***Business Models*** • Determine how to make money on transmission • Determine the best way to regulate transmission • Determine optimal ownership of transmission • Develop transmission value network

The initiatives and projects were assembled (see the Appendix of the Interim Report).

Interim Summary

Focus Areas ands Initiatives	Number of Projects
Component Optimization	**115**
Ratings	14
Equipment Reliability and Availability	36
System Reliability and Security	32
System Restoration	7
Equipment Efficiency	26
Capacity Additions	**22**
System Upgrades	10
System Configuration	7
New Components	5
Advanced System Operations	**90**
System Operability	34
Operating Information	56
Markets	**23**
Market Design	17
Market Operations	3
Business Models	3

We then classified the Transmission initiatives using three criteria:

- Stage of development
- Impact-Timing
- Identified gap between the current initiative and required effort.

First, initiatives were categorized by their stage of development.

Research	Development	Demonstration			Commercialization	
		Initial System Prototypes	Refined Prototypes	Pre-Commercial Activity	Market Entry	Market Penetration
•General assessment of market needs •Assess general magnitude of economics •Concept and Bench testing •Basic research and sciences (e.g., materials science)	•Research on component technologies •Development and initial of product offering •Pilot testing	•Integrate component technologies •Initial system prototype for debugging •Demonstrate basic functionality	•Ongoing development to reduce costs or for other needed improvements •"Technology" (systems) demos •Some small-scale "commercial" demos	•"Commercial" demonstration •Full size system in "commercial" operating environment •Communicate program results to early adopters/ selected niches	•Initial commercial orders •Early movers or niche segments •Product reputation is initially established •Business concept implemented •Market support usually needed to address high cost production	• Follow-up orders based on need and product reputation • Broad(er) market penetration • Infrastructure developed • Full-scale manufacturing

The impact-timing framework was used to describe the importance of an initiative to performance and cost.

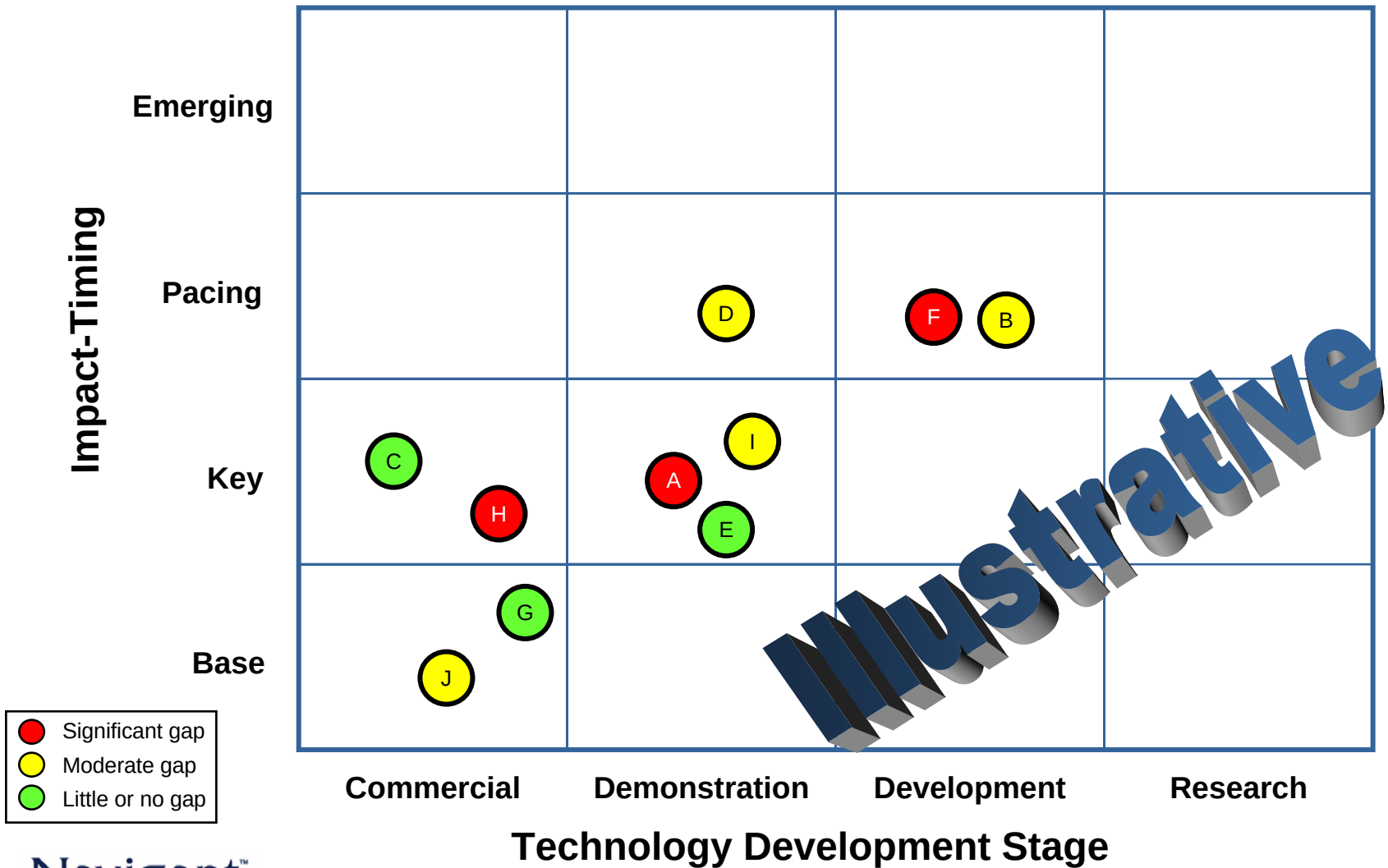
Level	Description
Base	Although essential to today's business, these technologies represent the common denominator in performance and cost.
Key	These technologies are important for performance and cost advantages for today's industry players.
Pacing	Although they are not fully embodied in current products, they may, if successfully applied, have a substantial impact on the performance and cost profile in the reasonably near future.
Emerging	These technologies may have a large impact on the performance and cost profile in the future, but this is far from certain.

Note: There is a normal progression from the Emerging technology level to the Base technology level as technologies become developed and more widely applied.

Finally, the degree to which research initiatives are being pursued was categorized

Designation	Description
Significant Gap	Few companies or entities are adequately pursuing this initiative at a level that will likely ensure the initiative has a reasonable chance of success to help resolve the issue it is addressing. This could indicate an area that has been overlooked or just emerging as a viable research initiative. However, it may be an initiative that is not appropriate or feasible to pursue at this time.
Moderate Gap	Continued and additional activity is likely required to ensure the research initiative has a reasonable chance of success to help resolve the issue it is addressing.
Little or No Gap	Little additional work beyond what is currently funded is necessary. There are many companies and/or entities pursuing this initiative. The current level of activity is likely appropriate to ensure the initiative has a reasonable chance of success to help resolve the issue it is addressing.

The R&D Initiatives were categorized by these three criteria: Impact-Timing, Technology Development Stage, and Gap.

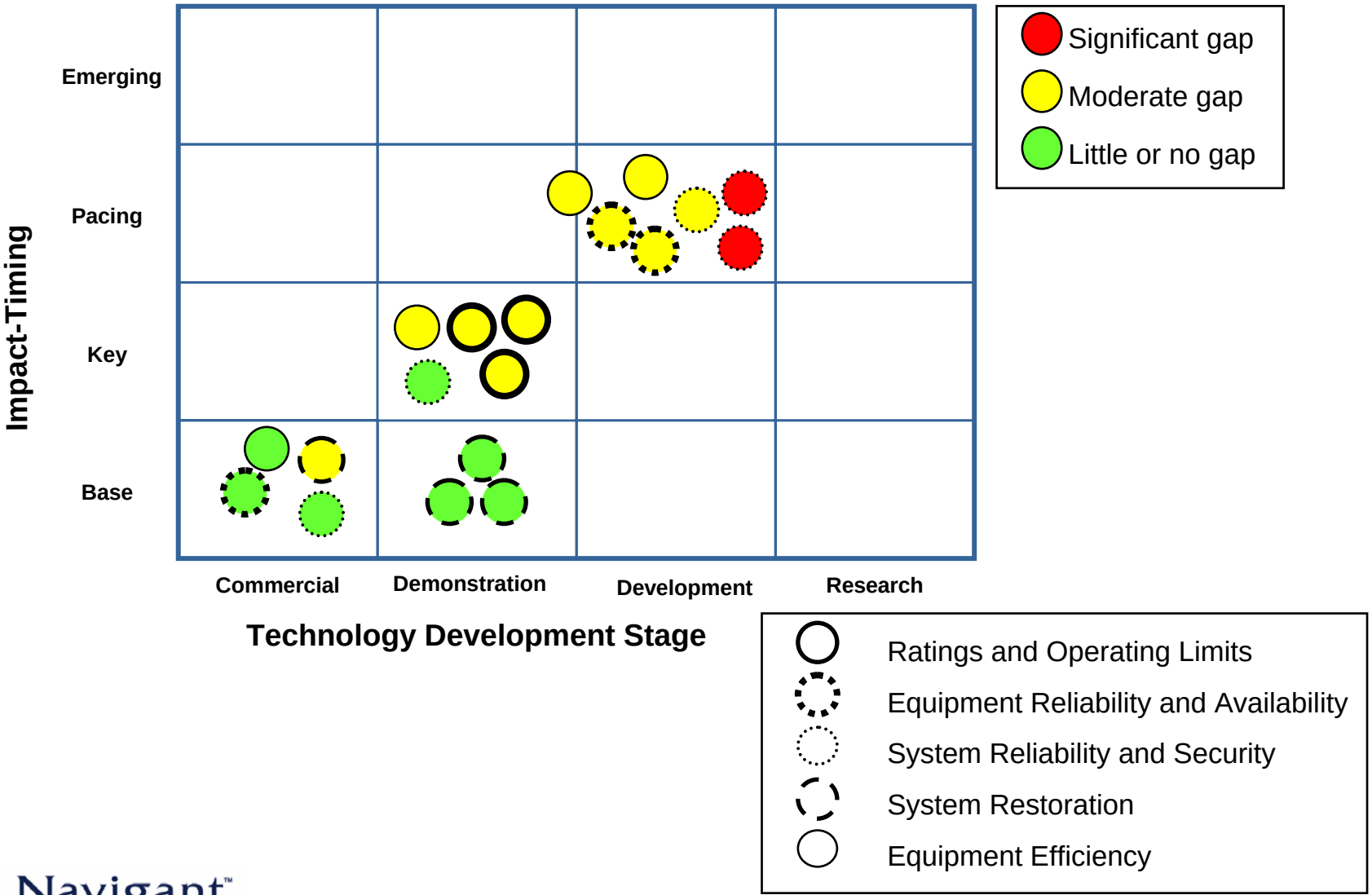


Workshop Presentation Agenda

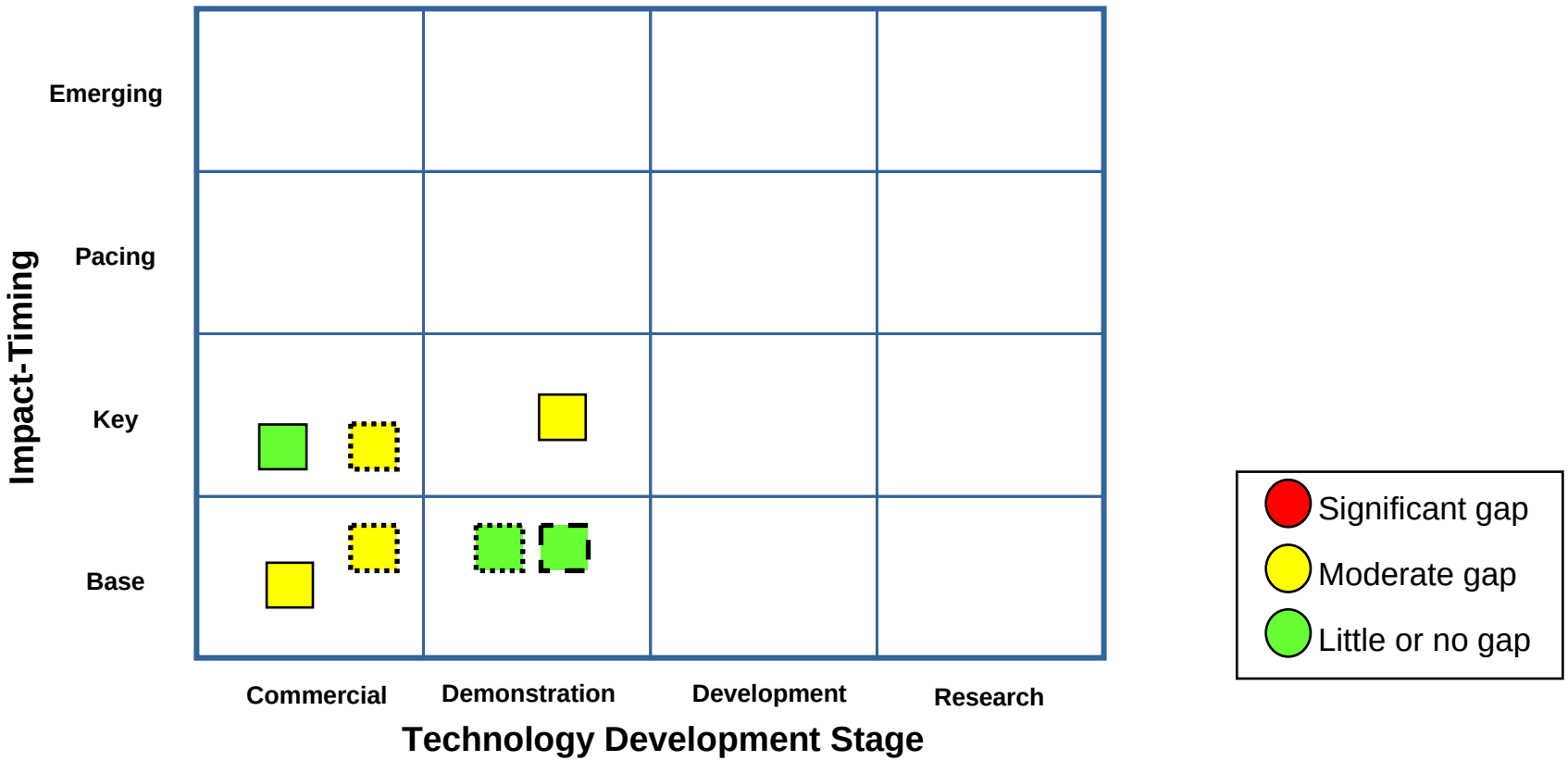
1 Methodology

2 Findings & Observations

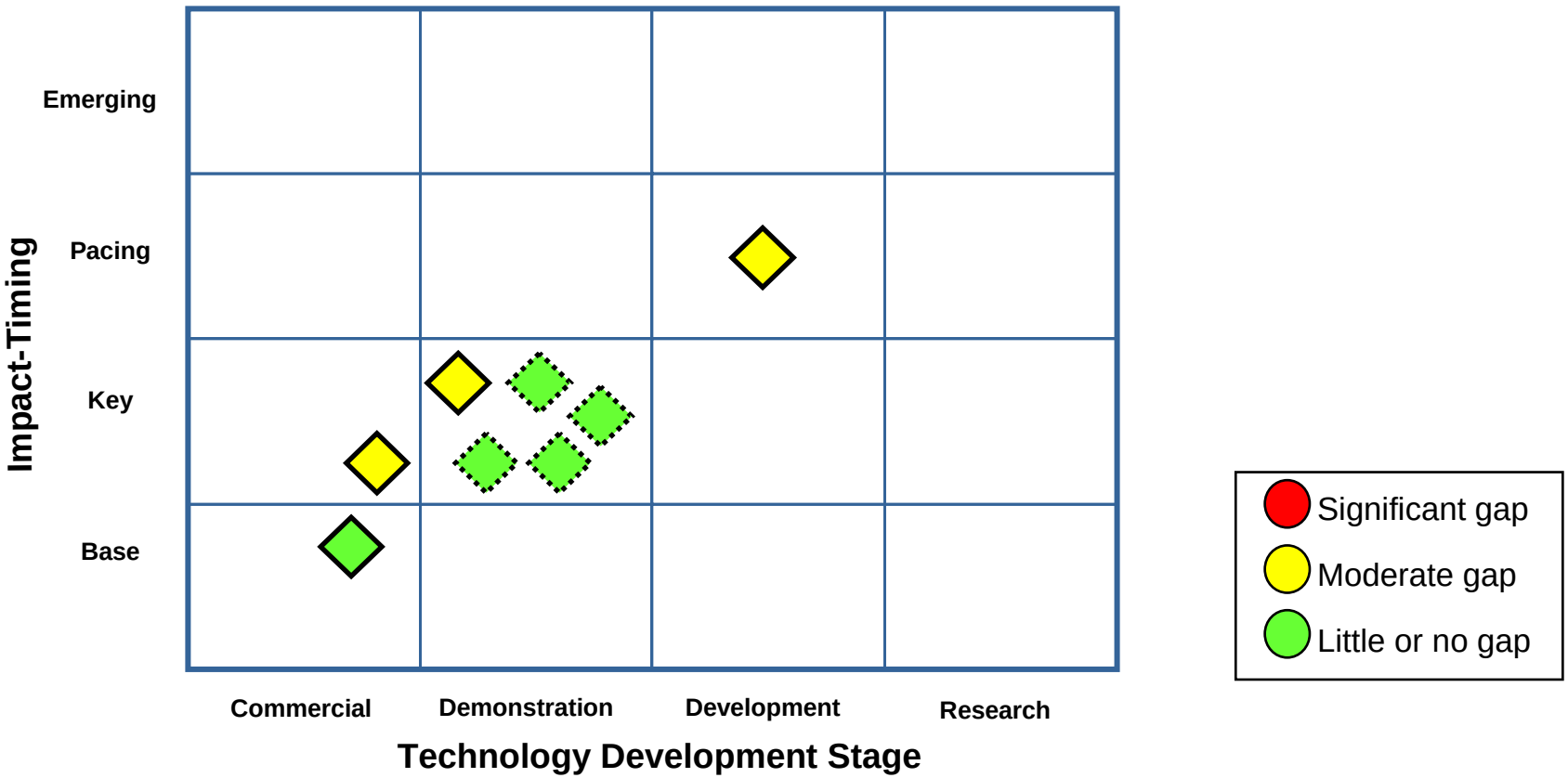
Component Optimization Research Initiatives



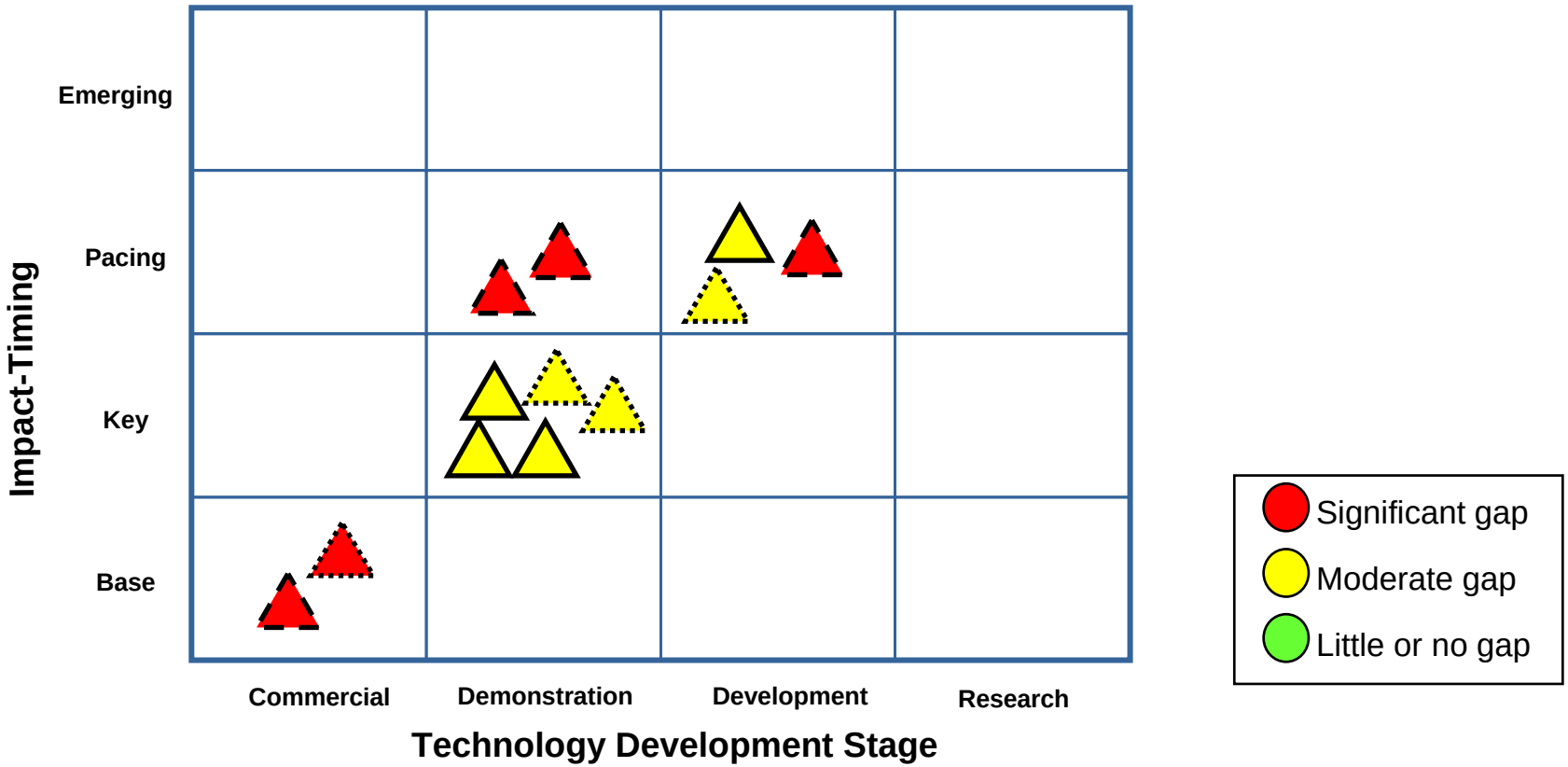
Capacity Additions Research Initiatives



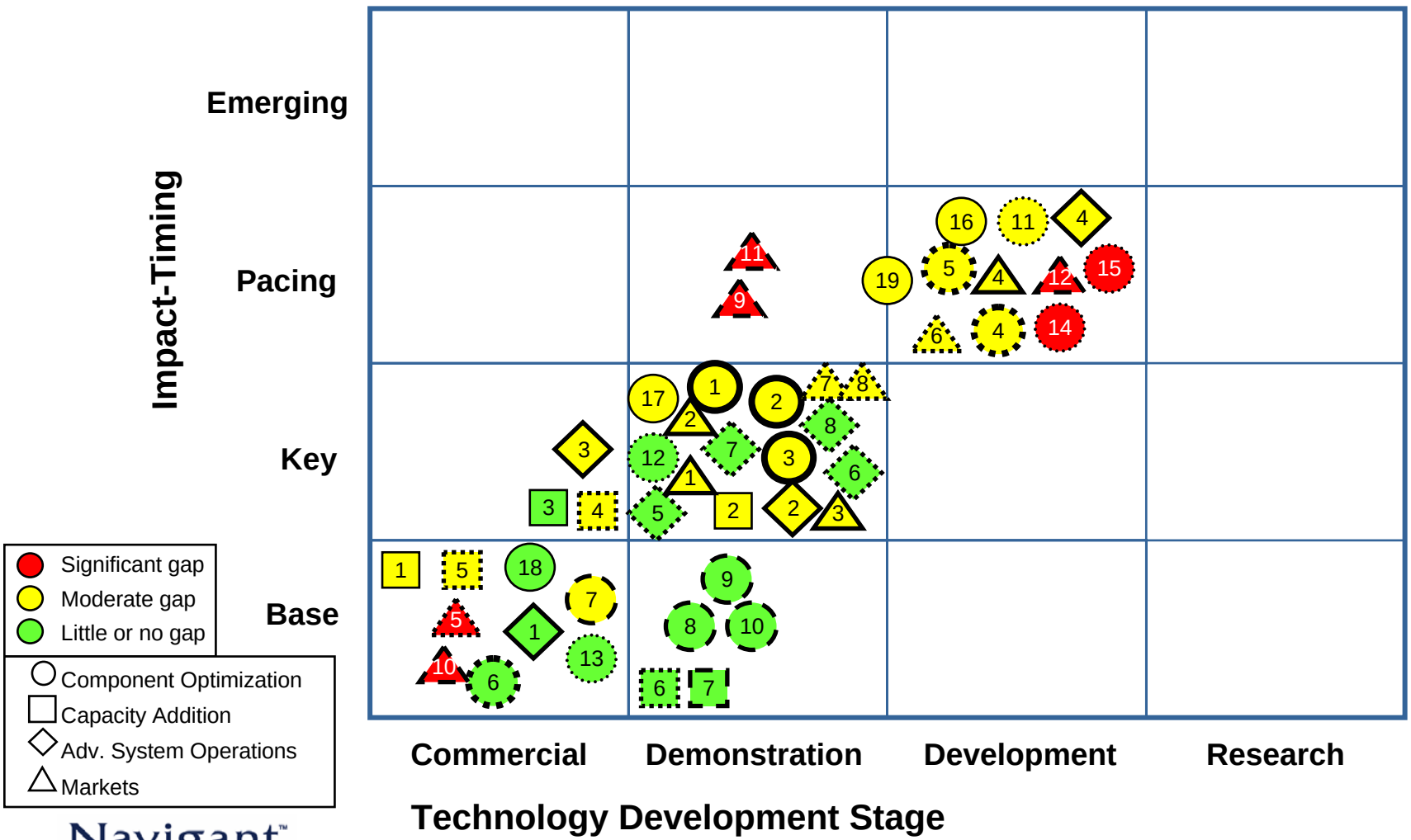
Advanced System Operations Research Initiatives



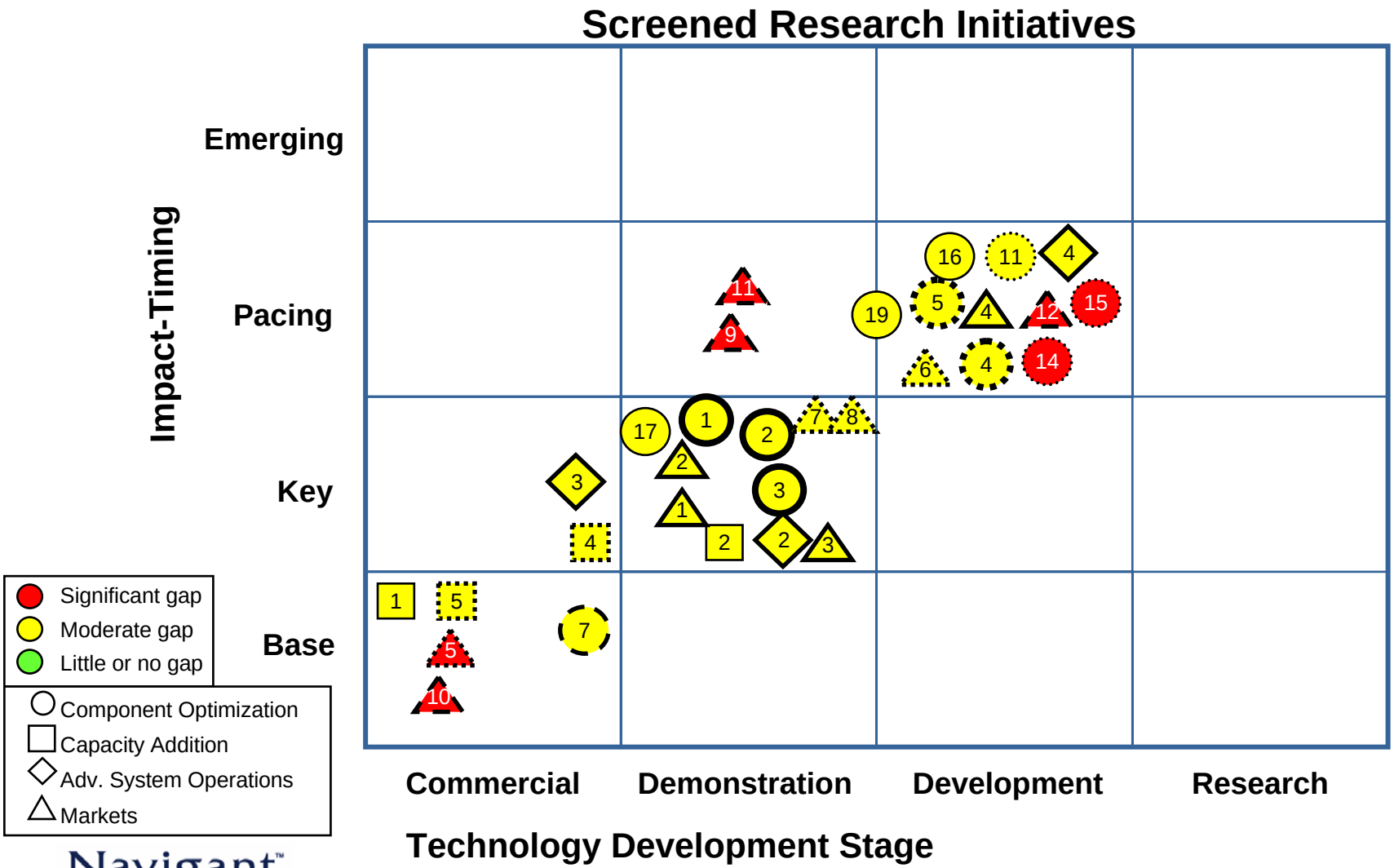
Markets Research Initiatives



Initial Set of Potential Research Initiatives



We screened out the initiatives with little or no gaps and identified research initiatives that have medium- to large gaps.

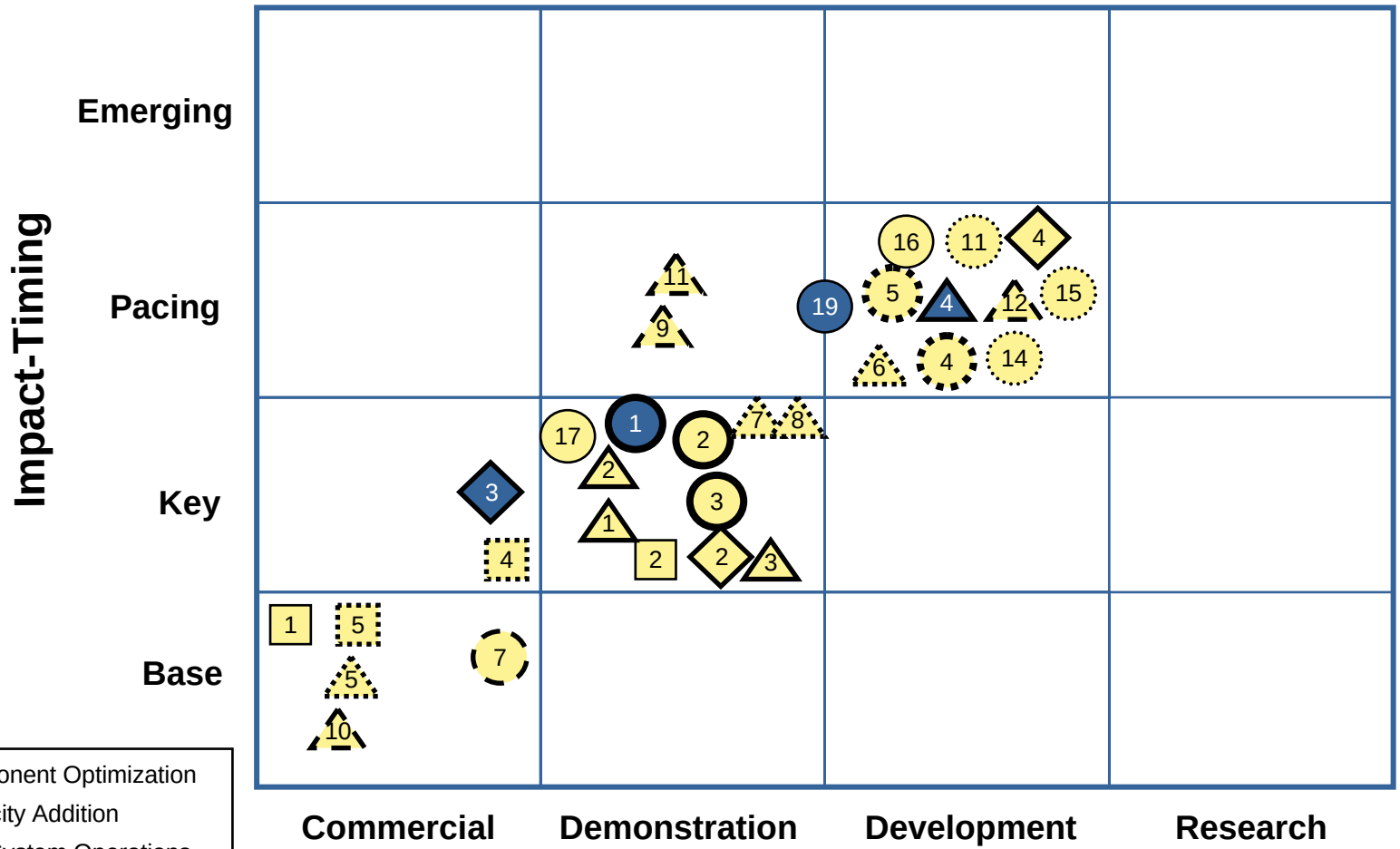


We then used the following criteria to initially select the the highest priority initiatives.

- Opportunities that clearly meet all four CEC/PIER funding criteria
- Opportunities believed to be lower risk
- Opportunities that appear to offer benefits to a relatively diverse stakeholder group, or that may be applicable to other CEC programs
- Opportunities that are considered technical in nature rather than related to policy
- Opportunities that, if successful, could create a large overall impact
- Opportunities for which the CEC can make a real impact by its participation

Based on these criteria, we identified four initial high priority opportunities.

Potential Research Initiatives



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In all, we have 31 attractive opportunities for consideration.

Component Optimization	**Ratings & Operating Limits**	1	Use actual system conditions in place of worst case conditions to increase thermal and stability limits
		2	Improve the cooling capability of equipment
		3	Develop new operating techniques
	Equipment Reliability & Availability	4	Adopt advanced materials that enhance the durability of system components
		5	Employ advanced design techniques that enhance the durability of system components
	System Reliability & Security	7	Increase the precision of system protection
	System Restoration	11	Develop self-healing networks
		14	Novel equipment/configuration design to manage failures and rapid system restoration
		15	Mechanized/automated repair
	Equipment Efficiency	16	Develop materials to increase efficiency of system components (e.g., HTS, ceramics, carbon fiber)
		17	Reduce the cost of transmission related technologies and components
		19	Apply storage technologies to enhance transmission capabilities
Capacity Additions	**System Upgrades**	1	Increase operating voltage
		2	Increase the capacity of the conductor
	System Configuration	4	Increase/simplify the application of DC transmission
		5	Develop novel phase configurations to increase capacity

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Potential High Priority Opportunity Additional Attractive Opportunity

In all, we have 31 attractive opportunities for consideration.

Adv System Ops	**System Operability**	2 Develop enhanced communications architecture 3 Integrate and streamline database and information systems 4 Develop expert systems to carry out complex control orders
Markets	**Market Design**	1 Develop mechanisms to value and assign capacity rights 2 Determine appropriate ancillary services 3 Develop effective hedging instruments 4 Develop modeling tools to test and simulate markets
	Market Operations	5 Identify ISO and Transmission Ownership requirements 6 Provide information and analysis to support bidding strategies 7 Develop systems to ensure transaction compliance 8 Develop rules and systems for congestion management
	Business Models	9 Determine how to make money on transmission 10 Determine the best way to regulate transmission 11 Determine optimal ownership of transmission 12 Develop transmission value network

Potential High Priority Opportunity Additional Attractive Opportunity

Workshop Presentation Agenda

1. Methodology
2. Findings & Observations
3. Discussion

Discussion Topics

- What do you see as the key issues/challenges facing the transmission sector?
- Do you believe that these challenges can be best addressed by technology, regulation or a combination of both?
- What perceived and real risks are affecting transmission R&D investment? What can be done to reduce those risks?
- What initiatives hold the greatest promise for meeting current and future challenges in transmission?
- What strengths can the CEC apply to meeting these challenges?
- Where should the CEC focus? Which initiatives are most attractive?
- What areas of transmission R&D should CEC avoid working in?
- What regulatory or policy changes could best meet these challenges?